

Chapter 15

Human Factors in Product Development and Design

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15.1 Introduction

The design and operation of product development processes are typical problems in engineering domains and quality management. In order to guarantee the efficient and effective realization of products various methods and tools have been developed and established in the past. Nevertheless these methods were usually designed to fit engineer-to-cost strategies for cost efficient products. Recent success stories of companies in different industrial sectors have proven, that engineer-to-value strategies can lead to an even higher profitability of products due to higher margins when combining value and cost orientation (ISO/IEC: 15288:2008; Schuh 2012). The two levers for engineer-to-value product management are illustrated in Fig. 15.1.

One of the major key elements for a successful introduction of engineer-to-value product management is the introduction and consideration of human factors. Therefore the integration of the customer in product development processes and the detailed analysis of the customer perception are essential (Brecher et al. 2014). The aspects concerning the role of customers in the product development will be presented in the first and second chapter of this paper. The third chapter will change the focus on the company perspective and will discuss new approaches and possible solutions how to develop products in a more efficient and human oriented way.

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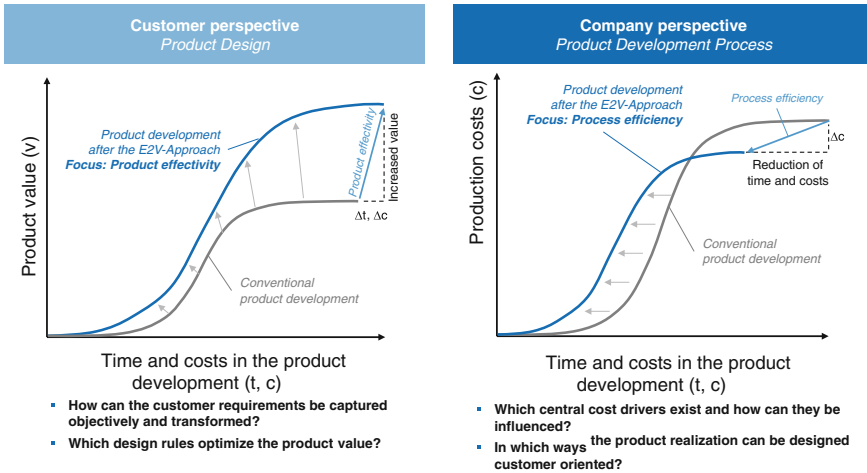


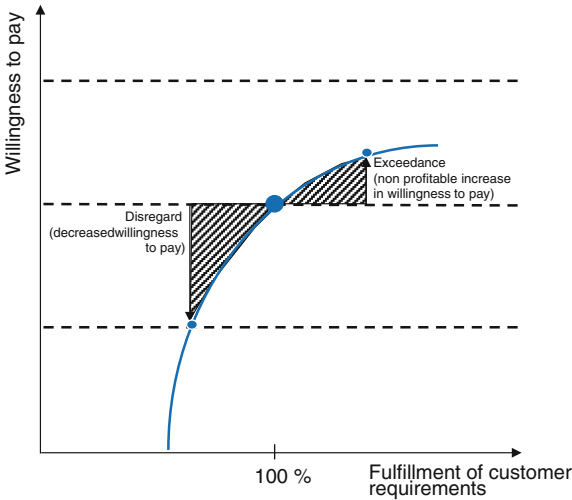
Fig. 15.1 Engineer-to-Value combines the effect of higher prices through an increase of product value while reducing the costs and time for product development and realization

15.2 The Human Perception of Quality

Customer satisfaction is a major component of a company's reputation and economic success. The relationship between a company and its customer base is established by and related to the quality of the products provided by the company. The degree to which customers are satisfied with a product results from the perceived quality of the product in question. The perceived quality of a product is the outcome of a cognitive and emotional mapping-process between the customer's conscious and unconscious experience, his or her expectations towards the product in theory and his or her experience with the product in practice (Schmitt et al. 2009). The amount of customer satisfaction correlates with the extent to which the product exceeds, fulfills or disregards the customer's requirements during real-life application (Homburg 2008). The disregard of customer requirements during product development and design leads to the customer's denial of the product resulting in a decreased willingness to pay. Furthermore, the exceedance of customer requirements (*over engineering*) is not profitable since customers hesitate to invest more money into product features which they do not necessarily require (see Fig. 15.2) (Masing 2007).

The degree of a customer's satisfaction with a product's quality changes during the progress of real-life application. The changes are due to a decrease or increase of the perceived value of the product over time whereupon the time period before and after the purchase designates the relevant time interval. During the pre-purchase phase, the customer gathers information about the product consulting family members and friends while simultaneously browsing through commercial web pages and social media platforms. The post-purchase phase refers to the period

Fig. 15.2 The impact of the degree of fulfillment of customer requirements on the customer’s willingness to pay (Value function; reproduced from Masing (2007))



of product usage and application (Schmitt and Amini 2013). The perceived value of a product consists of 13 unequally weighted factors such as brand, design, practicability, purchase price and follow-up costs. The customer perceived value (CVP) quantifies the trade-off between the customer’s perceived quality of a product and the customer’s perceived invest into the product (see Fig. 15.3) (Schmitt et al. 2014).

The extent to which customer requirements are met in product development and design is critical to a product’s market acceptance and success. The integration of customers into the early stages of product development and design becomes more and more important with respect to market leadership and differentiation, especially in flooded markets.

Fig. 15.3 Change of CVP during tablet use and application. The presented values represent the mean values of 36 test persons (own material)



15.3 The Manifestation of Human Perception and Cognition

Enthusiasing the customer and thereby ensuring a product's level of competitiveness requires the satisfaction of explicit and implicit customer requirements. The integration of customers into the early stages of product development and design allows for detecting the voice of the customer, whereupon explicit and implicit customer requirements constitute the "real" voice of the customer (Schmitt 2014). The fashion of explicit and implicit customer requirements is shaped by the individual customer's bygone experience, future expectations, actual needs and perception. The customer's perception of a product particularly relies on the human perceptual senses and their interconnection with the human cognitive system. Physiological and cognitive processes simultaneously designate the overall picture of perceived product quality.

83 % of the human perception is based on vision (Braem 2004). The initial visual perception of a stimulus is carried out by the mere visual system (*early vision*). The evaluation of what has been visually perceived is accompanied and influenced by the human cognitive system (Chen 2003). Therefore, the customer's gaze behavior delivers insights into how customers perceive and evaluate a product. Fixation points, direction and duration of fixation and saccades evidence the pathway of cognitive arousal (Nauth 2012). The pathway of cognitive arousal is predisposed by the product as such, its shape and design, its surface components and the individual customer's experience and expectations. As a result, increased cognitive arousal is associated with providing information about explicit and implicit customer requirements. Screen- and glasses-based eye tracking devices visualize the customer's gaze behavior and allude to stages of increased cognitive arousal (see Fig. 15.4). The pictorial manifestation of eye movement allows for further implications against the background of customer-oriented product development and design.

Whereas the human visual perception is concerned with "scanning" a product's visual properties, the human haptic perception provides information about a product's geometric and material characteristics. The geometric characteristics refer to the

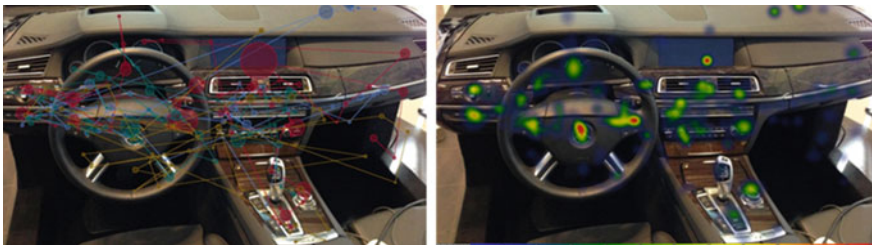


Fig. 15.4 Visualization of customer gaze behavior using eye tracking glasses. The *left* picture shows the fixation points and the direction of fixation for four test persons. The *right* picture depicts the duration of fixation for one test person (own material)

size and shape of a product. The material characteristics comprise a product's texture. The texture of a product can be described according to surface features such as roughness, stickiness, friction and stick-slip. In addition, thermal properties, compliance and weight contribute to the customer's haptic perception and evaluation of a product (Ledermann and Klatzky 2009). The exploration of a product's geometric and material characteristics is based on the physical contact between the customer and the product at hand. The nature of physical contact, be it pleasant or unpleasant, leads to increased cognitive arousal. Descriptive and discriminating studies guide the process of haptic exploration and facilitate the measurement of haptic perception and evaluation while mapping stages of increased cognitive arousal to distinct surface properties (Clark et al. 2008). The focus lies on examining and labeling the customer's hedonic perception during the phase of physical contact.

Electroencephalographic devices (EEG) connect the stages of increased cognitive arousal during visual and haptic perception to participating brain areas (*neurofeedback*). The visual information is transformed into electronic signals leading to enhanced brain activity. The measurement and location of enhanced brain activity provides insights into brain areas participating during the processes of product perception and evaluation (Babic and Damnjanovic 2012). Likewise, devices quantifying the amount of electrodermal activity (EDA) evidence stages of increased cognitive arousal. The human vegetative nervous system controls for perspiration (*biofeedback*). Hence, ascending perspiration accounts for increased cognitive arousal (see Fig. 15.5) (Wagner and Kallus 2014).

Besides sensory information also verbal information is taken into consideration for the purpose of customer-oriented product development and design. The customer's perception and evaluation of a product becomes manifest in textual form appearing as recommendations or complaints. Since social media applications are the primary means of communication nowadays, customers articulate their recommendations or complaints referring to a given product using online communication platforms (Mast 2013). 62 % of all potential customers consult online reviews for advice prior to deciding in favor for or against the purchase of a product (Lightspeed Research 2011). 81 % of all potential customers base their purchase decision solely on the reception of prior customer reviews (E-Tailing Group 2007).

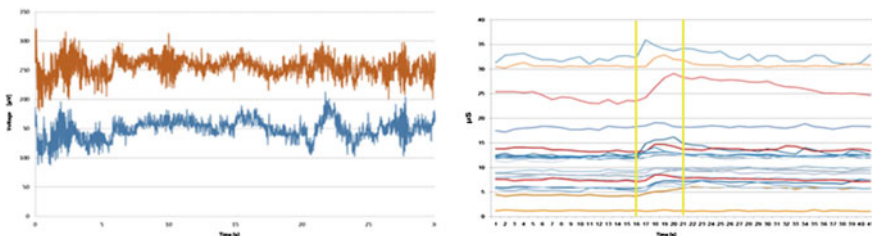


Fig. 15.5 Visualization of electroencephalographic and electrodermal activities. The *left* picture shows the electroencephalographic activities for 2 test persons. The *right* picture depicts the electrodermal activities for 21 test persons during the evaluation of differing sound signals. The *two yellow lines* indicate the occurrence of noise distraction (own material)

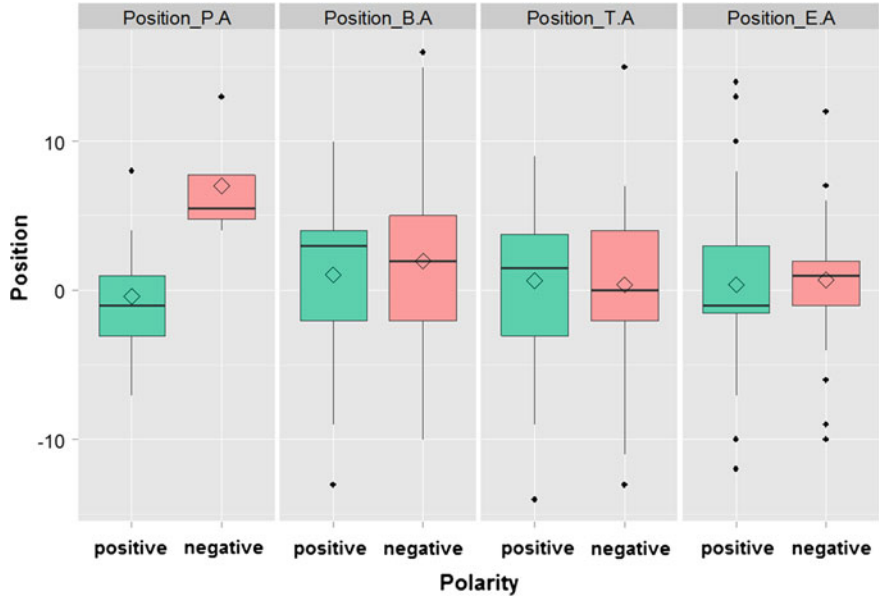


Fig. 15.6 The influence of polarity on attribute position relating to keywords referring to products, brands, types or elements (own material)

The integration of social media applications during the process of customer requirement analysis provides several benefits with respect to the number of available data, the actuality of data and the authenticity of data. The number of available data necessitates the automatic detection, extraction and analysis of relevant user generated content. Opinion mining tools facilitate the above named process relying on machine learning or lexicon-based approaches (Liu and Zhang 2012; Manning et al. 2008; Baccianella et al. 2010). Moreover, the integration of individual grammatical features which constitute the overall linguistic structure of either recommendations or complaints has the potential to increase the accuracy of existing opinion mining tools (see Fig. 15.6).

The integration of the human factor into production processes ensures the realization of products which exactly serve the customers needs. The customer’s perceptual senses, cognition and communication behavior deliver valuable input for the process of product development and design.

15.4 Human Oriented Product Development Processes

While the first chapters were addressing the consideration of human factors in the early phases of product realization processes, the company oriented perspective has to consider the human factors of the product development team itself.

The new product development process (NPD) is one of the most important and complex business processes. In order to compete in globalized markets it is necessary to develop products within short time periods and a defined quality level (Barclay et al. 2010). For complex products, the team of a single product development project can exceed easily the scope of a small and medium enterprise by its own. Because of the high amount of functions and people involved (e.g. systems engineering, mechanical engineering, software development, electronic development, project management, product management, industrial engineering) the NPD is characterized by a high complexity, non-linearity and permanent iteration which drive the affordable level of communication and coordination to an extreme. This state is difficult to be controlled (Loch and Kavadis 2008). As illustrated in Fig. 15.6 the methods and activities of quality management are aiming towards a collaborative management of the maturity levels in the fields of project, product, process and contract management.

That is, a new product development project will be successful if the information of the involved actors is allocated in an efficient and effective way, minimizing the amount of failures and iterations due to rework of tasks and assignments. The distribution of information and synchronization of different product and process releases (the maturity levels) is one of the biggest challenges for quality and requirements management. Experts in product development know: the higher the dependence and connectivity of information, the more challenging the planning affords for the information distribution and synchronization between tasks and actors are. Especially delays can cause massive instabilities in the product development system due to an increasing amount of rework and failures (Schmitt and Stiller 2013). The information dependence of requirements and information is illustrated in Fig. 15.7.

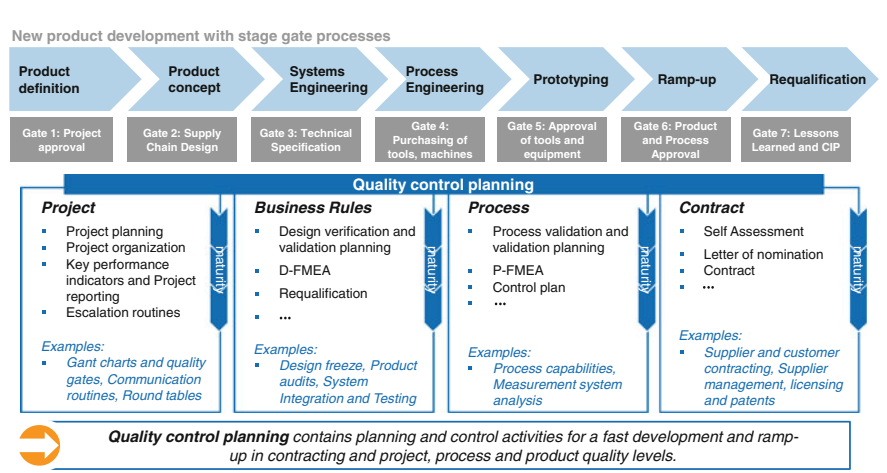


Fig. 15.7 Quality planning and control in new product development processes

If for example the industrial engineering is informed with a certain delay about a change request of the mechanical component, a later change can cause massive extra costs and delays.

Furthermore, the different functions are working according to different development paradigms and models. That is, the project management might stick to the stage-gate-planning, while the systems engineering is applying the V-Model and the software engineering might even develop according to the rules and procedures of agile development methods such as SCRUM. Therefore the communication and synchronization of different functions and actors is even complicated, since the models cannot always be harmonized and synchronized easily. In order to support the activities in product development and realization processes, various expert tools and software systems are used besides informal and formal communication links and channels (e.g. meetings, logs, records, minutes, mails). Requirements management systems, change management software tools and product lifecycle management systems are powerful tools supporting the product development activities within their domain. Within the field of a single domain the applied software systems must be chosen specifically depending on special functions and domain specific requirements. That is the reason for the necessity of using different tools for quality inspection planning (MS-Project, MS-Excel), risk analysis and for production control planning (e.g. CAQ-Systems, SCIO, APIS).

Last, but not least, the employees tend to get lost within the complexity of product development systems and tools. The amount of different methods can hardly be understood and not even be overseen by a single product development team member. Nevertheless the state-of-the-art software systems and methods are by majority emphasizing the system and workflow view instead of putting the employee and his human factors in focus. The allocation of information based on defined rules, regulations is more important than considering the individual competencies and characteristics of the employees. Due to the described complexity of the organization of product development processes and teams, the planning tools might eventually cause a loss of relevant information and can hardly cross the borders between different development domains and functions.

In order to improve the described state-of-the-art of product development processes, a more human oriented understanding and perception of product development initiatives must be challenged. This affords the change in understanding that the product development process is not solely a technical, but rather a socio-technical system. The information flow and allocation can be regarded in analogy to the rules and behavior in social networks: Agents, with different characters, skills and from different cultures and domains are working on the creation of information which they are likely to share with their principles, due to their individual problems and interest. Hence, a more integrated, human oriented software system would create a social engineering community where information is spread using either workflow and rule based algorithms or social mechanisms and effects. The information-pull mechanism of a social network will decide which agents and information are important and must be followed by the principles, while the information push channels are securing the minimum level of standards and workflows.

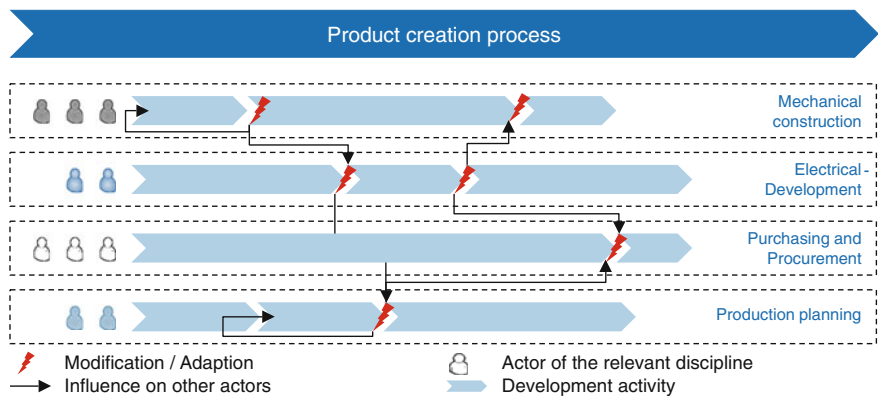


Fig. 15.8 Quality planning and control in new product development processes

Figure 15.8 illustrates the general concept of the social engineering network. When an agent generates information which has importance for a principal within or outside the development team (e.g. line manager, company experts) an algorithm will distribute the information based on a set of parameters (e.g. organization, functions, workflows, dependencies, risks, behavior of employees) (Fig. 15.9).

The design of new product development theories and systems, integrating the existing methods and tools will be one of the great challenges for major improvements in product development processes and for the optimization of the

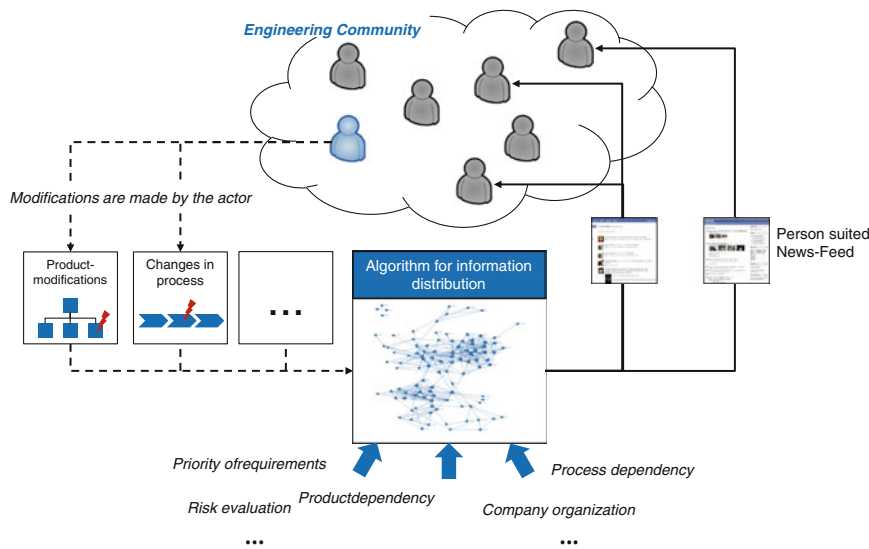


Fig. 15.9 Social engineering network and distribution of information

company perspective in engineer-to-value product management. Moreover, the described methods for the identification and transformation of the customer's perceived quality can increase the value of products significantly.

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